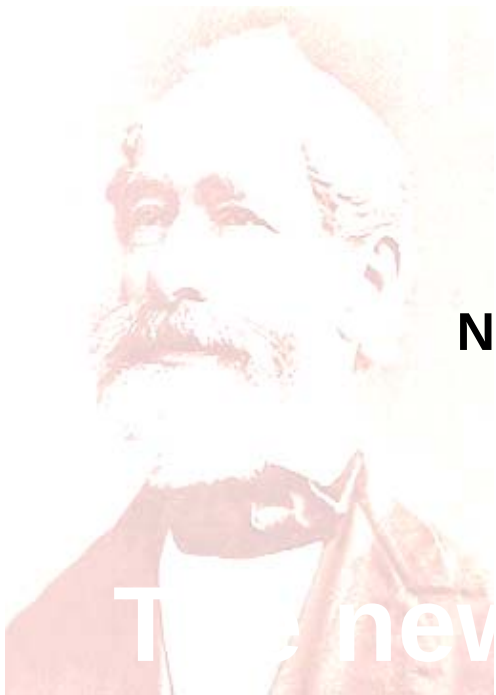
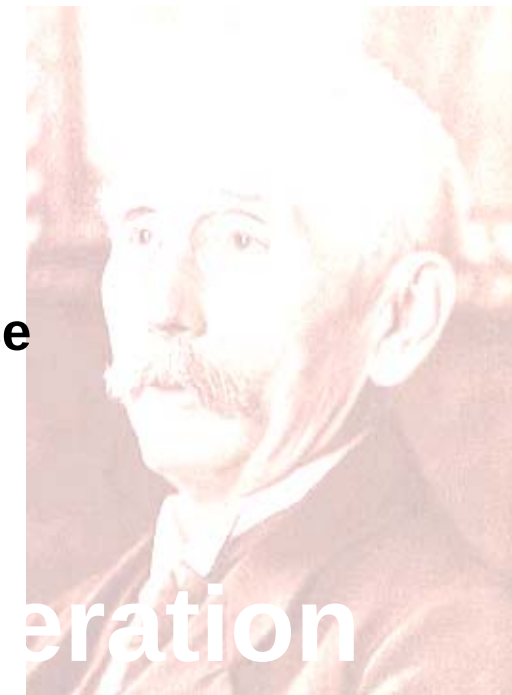
Carl Zeiss Industrial Metrology

Algorithms





October 2005

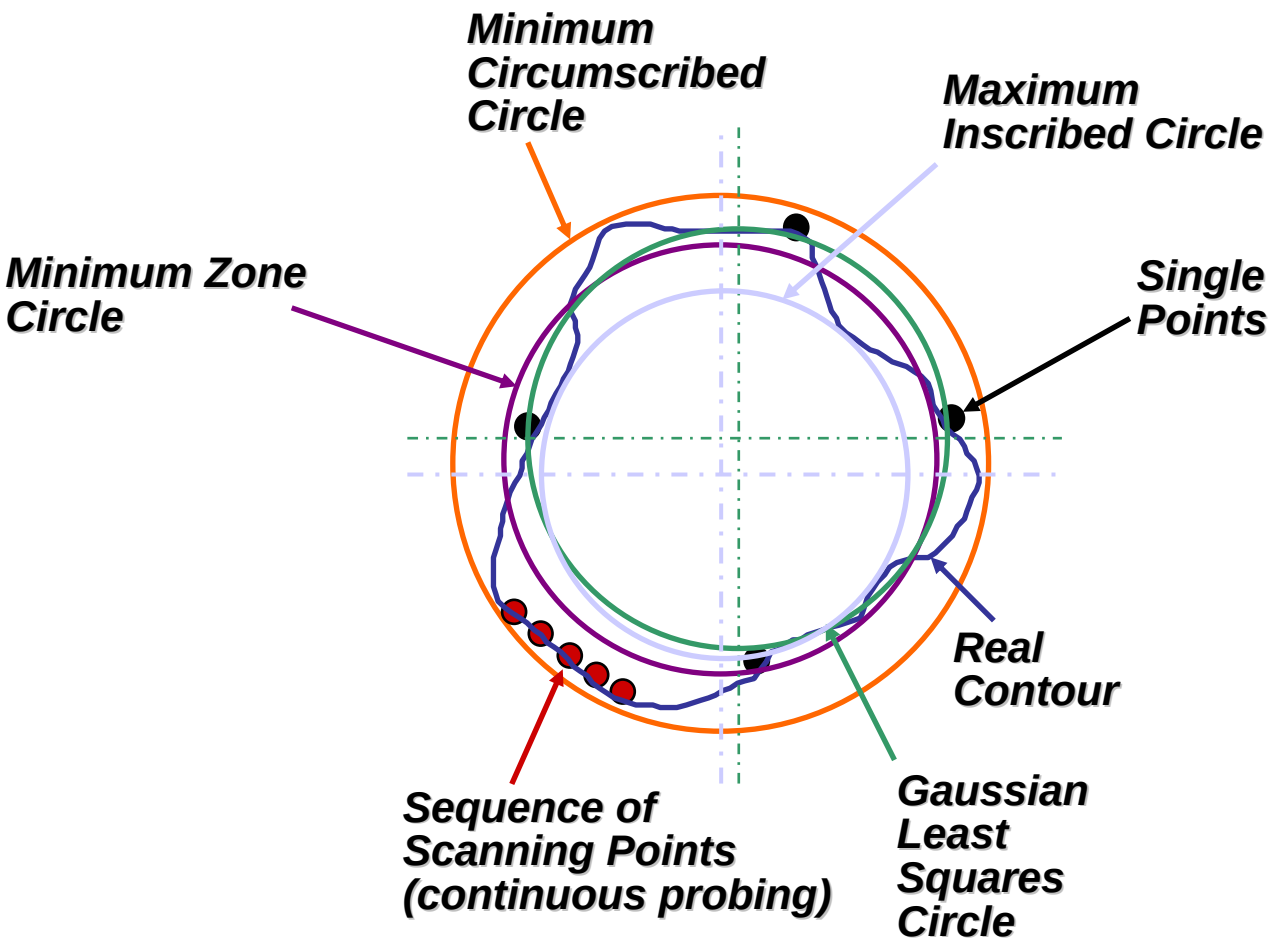
National User Group Conference

Richard Knebel

VP Engineering – Carl Zeiss

Algorithms

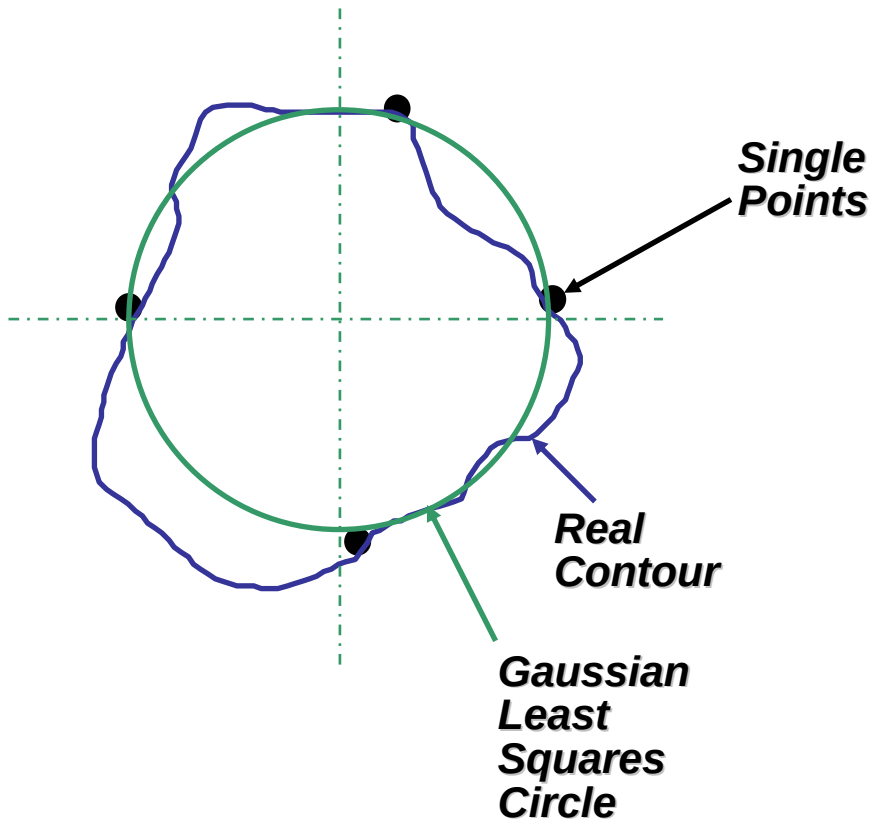
We make it visible.



Why Least Squares ?

We make it visible.

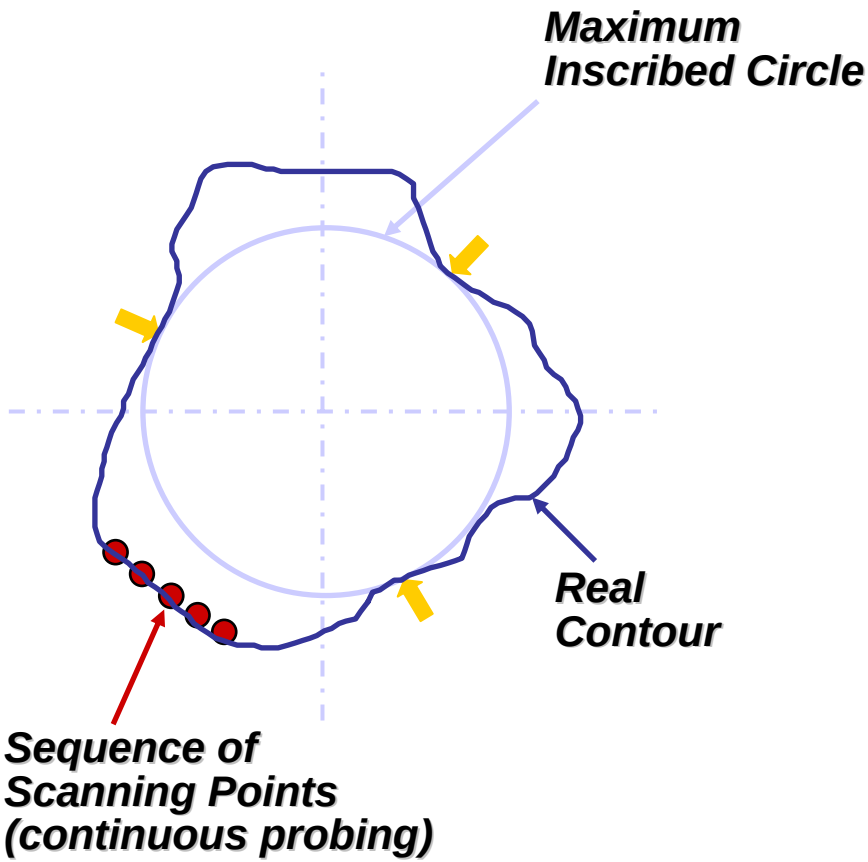
- **Provides a consistent, stable result**
- **Consistently provides the**
  - **Wrong Size**
  - **Wrong Location**
  - **Wrong Form**



Why Maximum Inscribed ?

We make it visible.

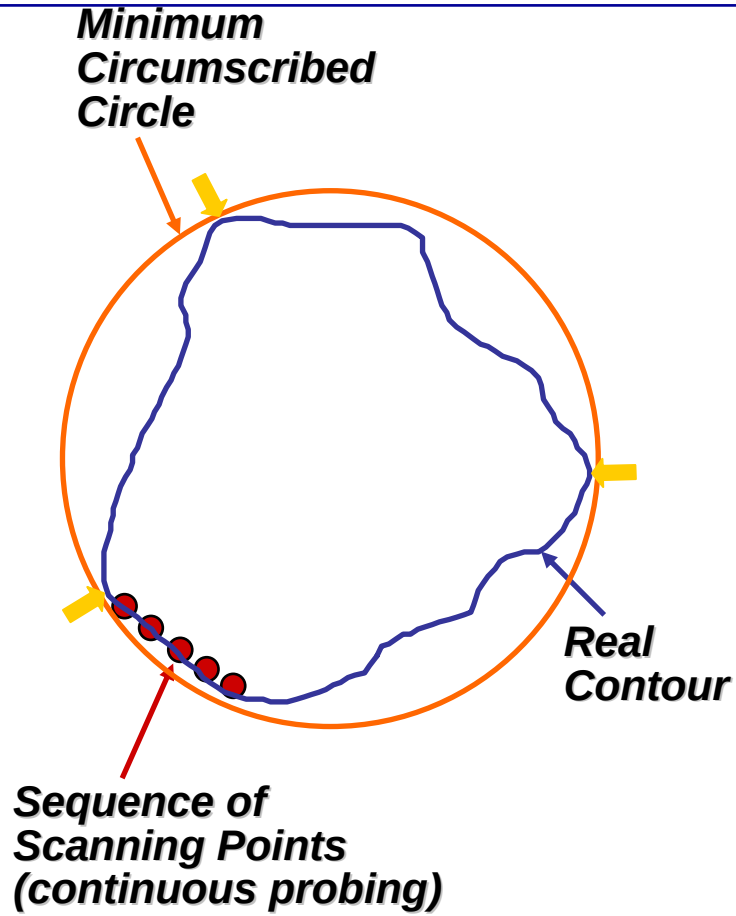
- **Provides the correct result for**
  - **Size**
  - **Location**
- **On *internal* diameters**
- **When used with enough data density**
- **However it is not as stable as Least Squares because..**
  - **It fits on extreme points**



Why Minimum Circumscribed ?

We make it visible.

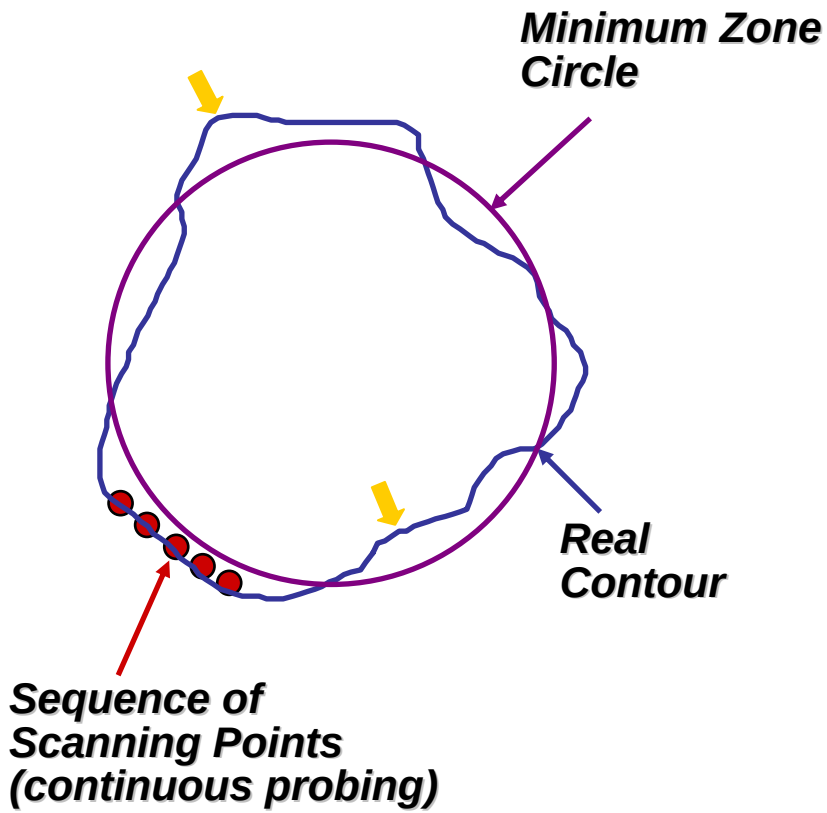
- **Provides the correct result for**
  - **Size**
  - **Location**
- **On *external* diameters**
- **When used with enough data density**
- **However it is not as stable as Least Squares because..**
  - **It fits on extreme points**



Why Minimum Zone ?

We make it visible.

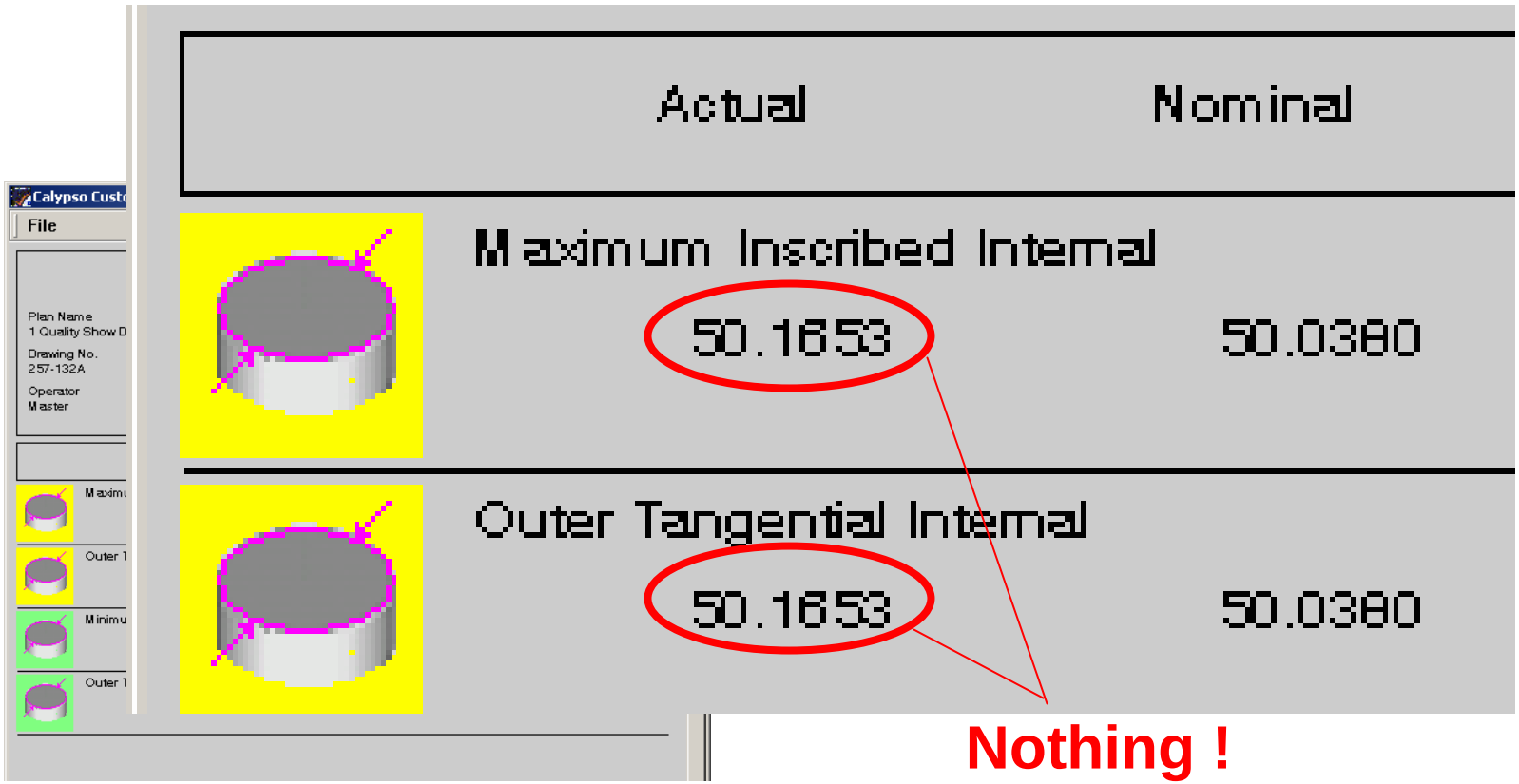
- **Provides the correct result for**
  - **Form**
- **When used with enough data density**
- **However it is not as stable as Least Squares because..**
  - **It fits on extreme points**



What about Inner and Outer Tangential ?

We make it visible.

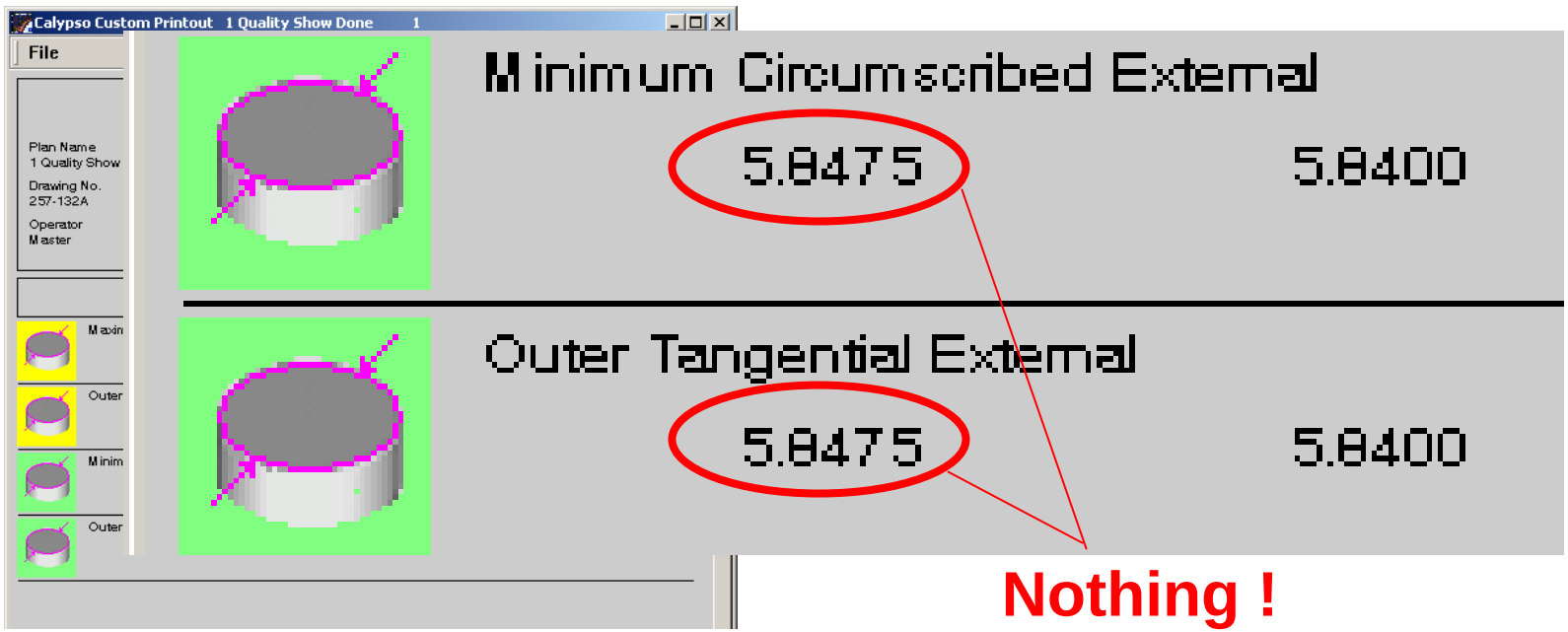
- **What's the difference between Outer Tangential and Maximum Inscribed on an *internal* diameter ?**



What about Inner and Outer Tangential ?

We make it visible.

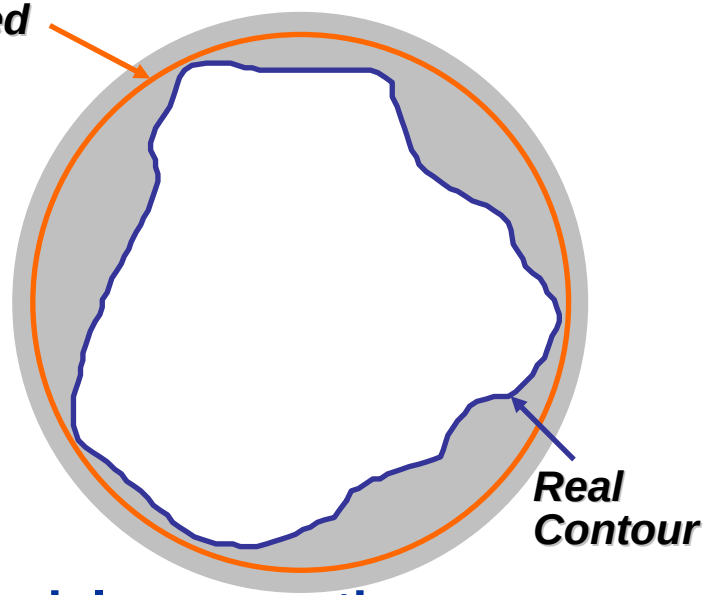
- **What's the difference between Outer Tangential and Minimum Circumscribed on an *external* diameter ?**



What about Inner and Outer Tangential ?

We make it visible.

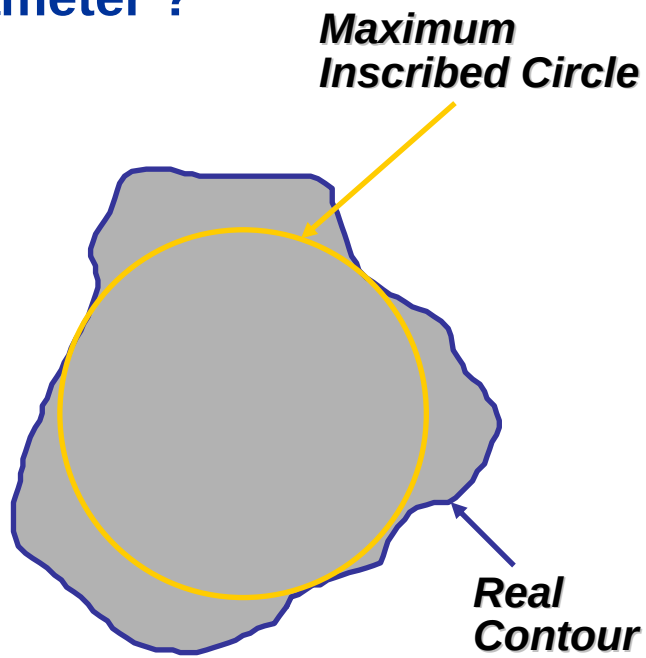
- What's the difference between Inner Tangential and Minimum Circumscribed on an ***internal*** diameter ?
- Nothing !
- Is this a functional mating size fit?
- No !
- When might you use it ?
- To determine if there is enough material on a casting so that it will cleanup during machining, to evaluate the maximum size, or to evaluate wall thickness



What about Inner and Outer Tangential ?

We make it visible.

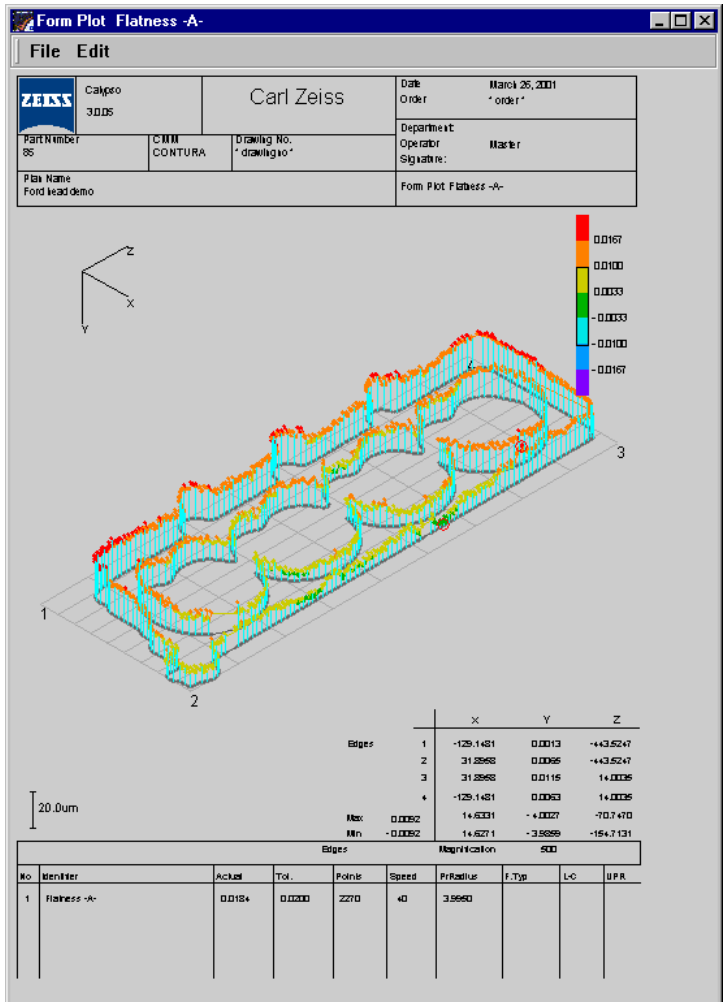
- What's the difference between Inner Tangential and Maximum Inscribed on an *external* diameter ?
- Nothing !
- Is this functional mating size fit?
- No !
- When might you use it ?
- To determine if there is enough material on a casting so that it will cleanup during machining, to evaluate the minimum size, or to evaluate wall thickness



So why do we have Inner and Outer Tangential ?

We make it visible.

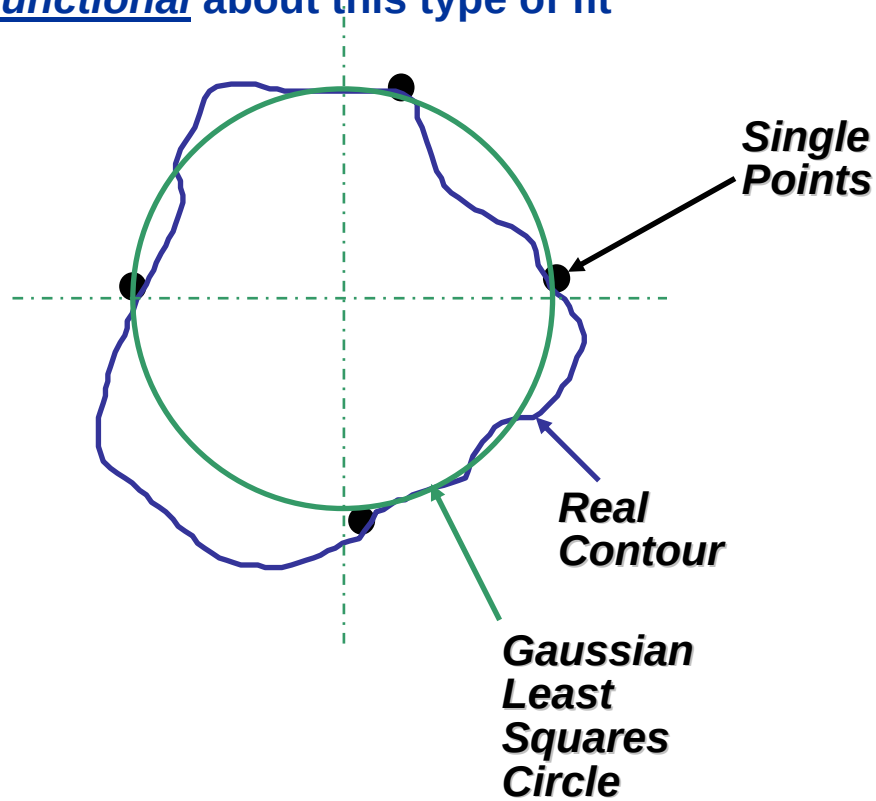
- **Because it is more descriptive for Planes and Lines**



So lets generalize the math

We make it visible.

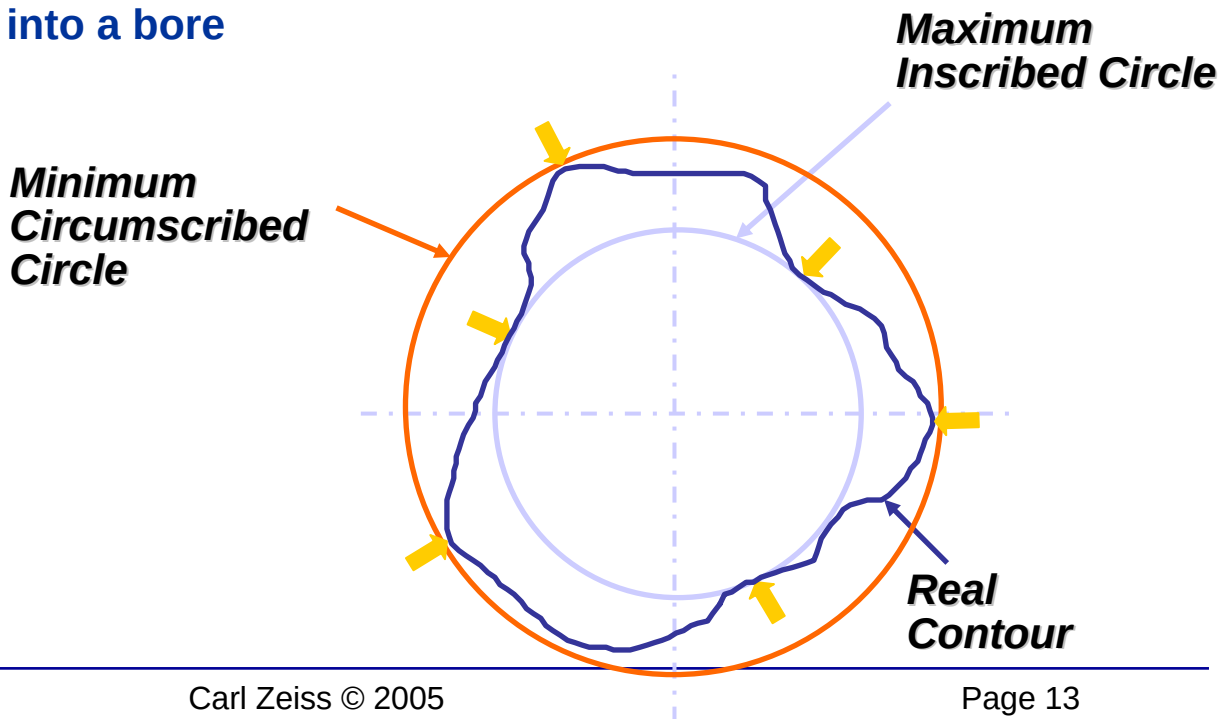
- **We have Gaussian Least Squares fits which minimize the square root of the sum of the squared errors**
  - **In this type of fit all data points have the same weight in determining the fit**
  - **There is *absolutely nothing functional* about this type of fit**



So lets generalize the math

We make it visible.

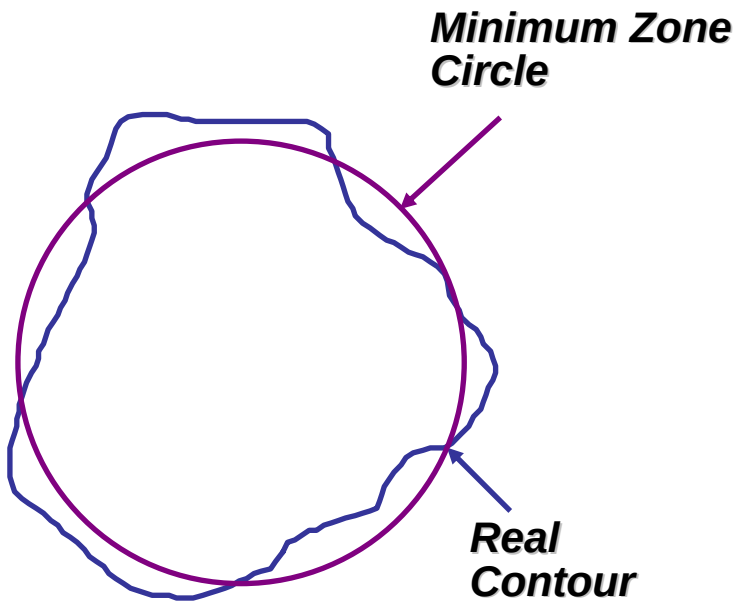
- **We have *extrema* fits (Inner and Outer Tangential, Max Inscribed, Min Circumscribed) which fit on the high points of the feature**
  - **In this type of fit only the high points have any weight in determining the fit**
  - **This is *absolutely functional* fitting for size and location like when mating a plane against a granite surface plate, or finding the slip fit pin that just fits into a bore**



So lets generalize the math

We make it visible.

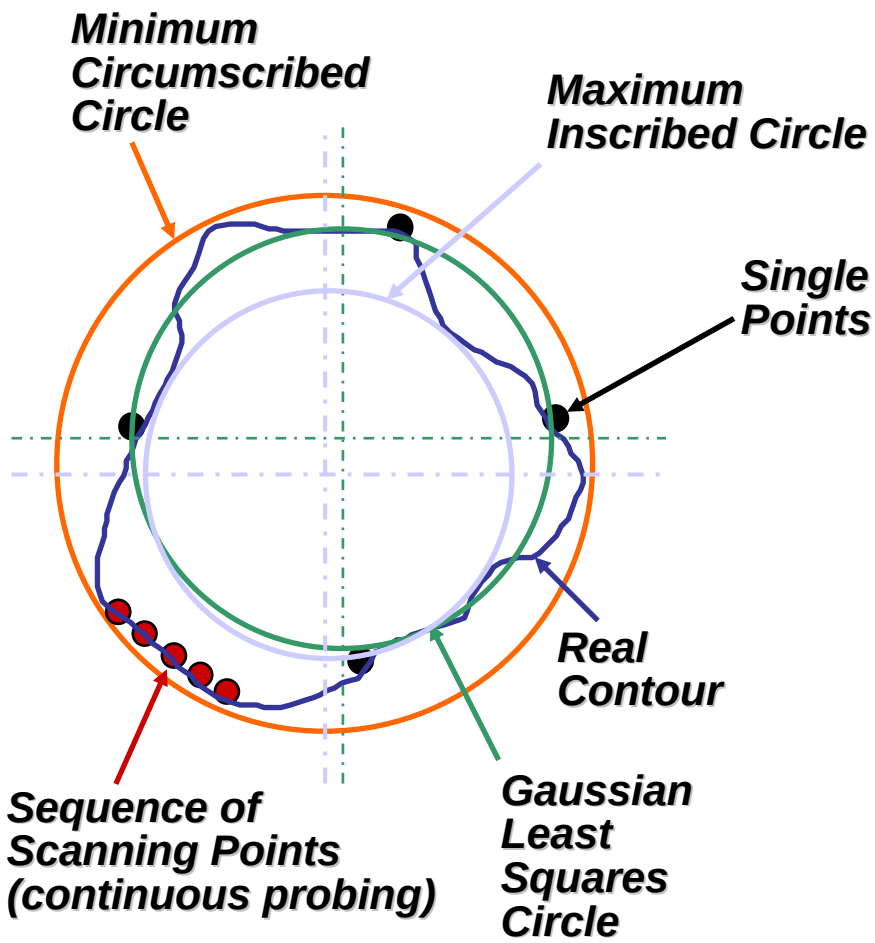
- **We have *minimum zone* fits which equally balance the high and low point of the feature**
  - **In this type of fit only the high point and low point have any weight in determining the fit**
  - **This is *absolutely functional* fitting for form analysis**



Summary

We make it visible.

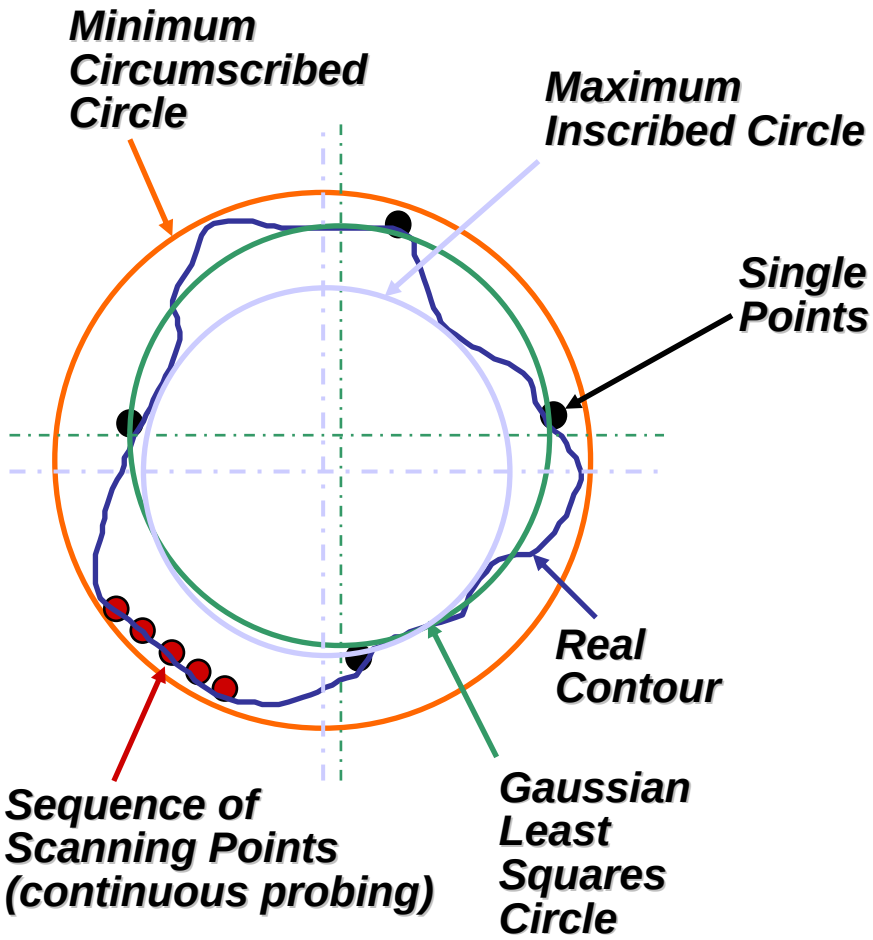
- Know the basic best math of each algorithm
- Understand the potential difference (pros and cons) each algorithm can provide
- Apply the algorithm that meets the needs of the application accordingly
- There is no one simple rule that can define what to use and when, as a CMM programmer, you must help decide what is best on a case-by-case basis



Summary

We make it visible.

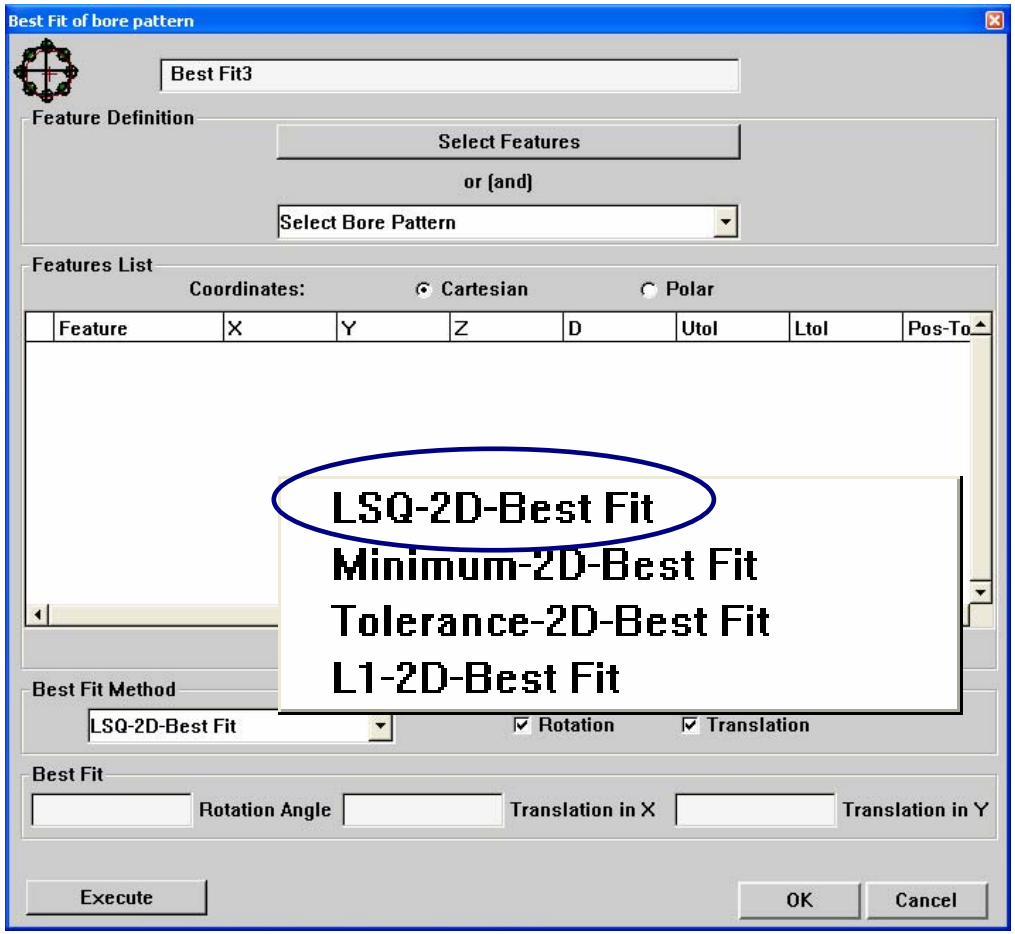
- **You need to consider**
  - **Data density**
  - **Purpose of the measurement**
    - Accept / Reject
    - Process control
  - **Correlation concerns**



Bore Pattern Algorithms

We make it visible.

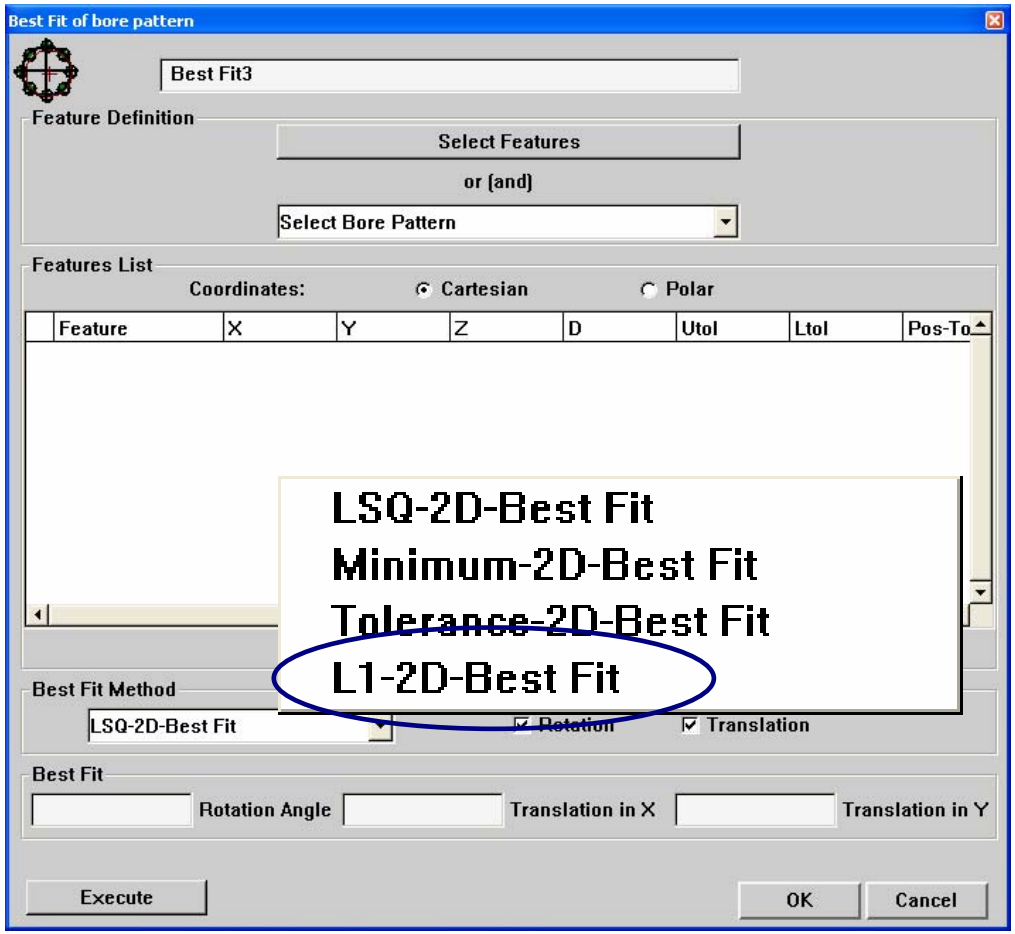
- **LSQ –2D Best Fit**
  - **Textbook math (Gauss) that minimizes the square root of the sum of the squared deviations**
  - **In certain cases it can reject a good part**
  - **Best use is for understanding the process, not for accept/reject analysis**



Bore Pattern Algorithms

We make it visible.

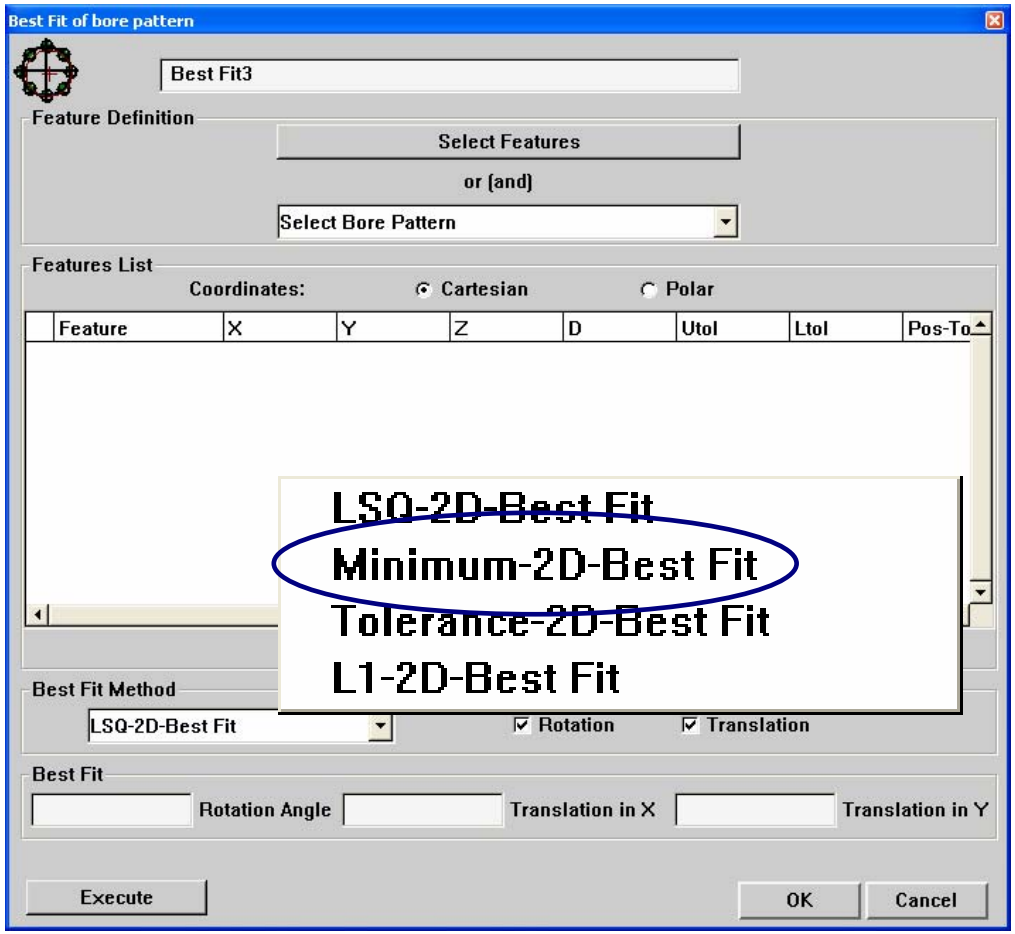
- **L1 –2D Best Fit**
  - **Zeiss math that tries to show the worst case error more clearly**
  - **In certain cases it can reject a good part, and will do so more than LSQ**
  - **Best use is for understanding the process, not for accept/reject analysis, and it does this better than LSQ at showing the process problem**



Bore Pattern Algorithms

We make it visible.

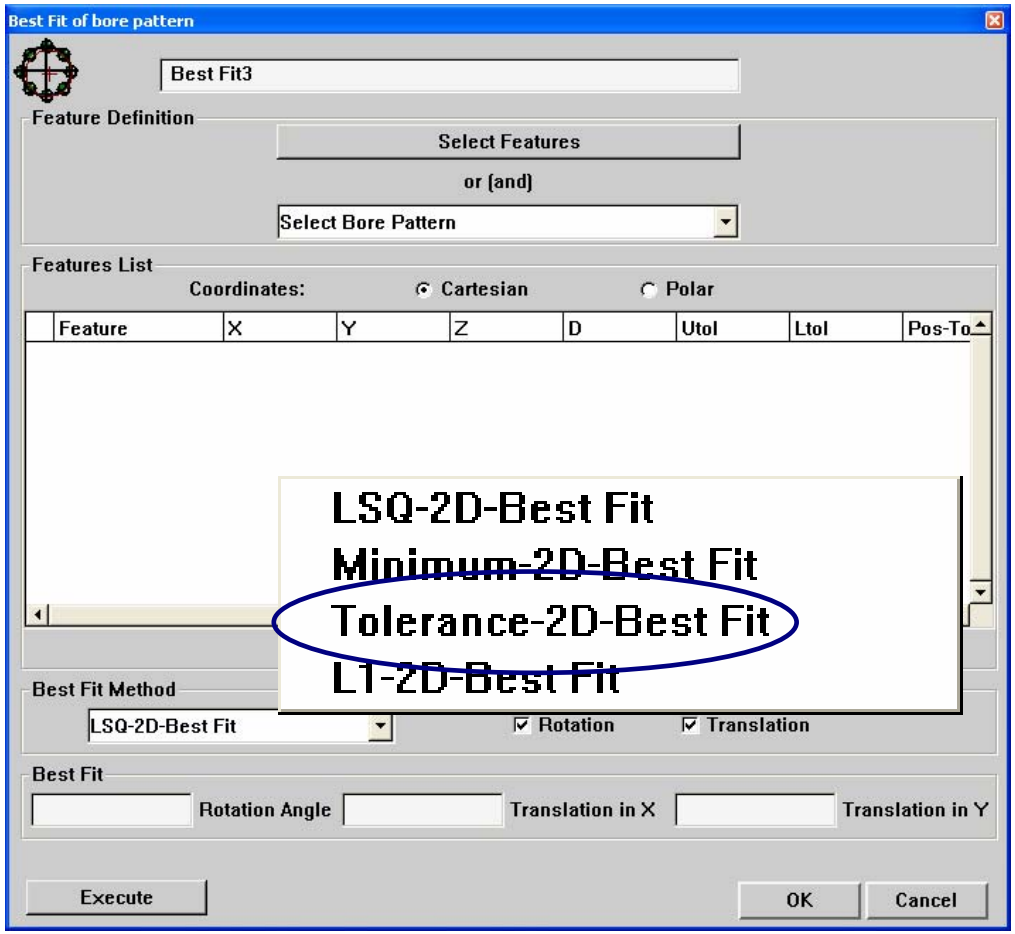
- **Minimum –2D Best Fit**
  - **Textbook math (Tschebychev) that minimizes the maximum deviation**
  - **Will at times reject a good part, but less frequently than LSQ**
  - **Best use is for accept/reject analysis**



Bore Pattern Algorithms

We make it visible.

- **Tolerance –2D Best Fit**
  - **Zeiss math that iteratively tries to accept the part like you would with a hard gage**
  - **Will accept the maximum number of parts**
  - **Best use is for accept/reject analysis and does a better job than Minimum**



Carl Zeiss Industrial Metrology

Questions